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Relative Resistance of Tomato Varieties, Selections, and Crosses to Defoliation by Alternaria and Stemphylium [1]

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INTRODUCTION

As more emphasis has been placed on vegetable production in the South, attention has been drawn by tomato growers to the damage done to crops as a result of premature defoliation of the plants by leaf spot fungi. Under prevailing summer growing conditions, adequate leaf coverage of fruit is necessary to insure a profitably long picking season and even, in some cases, a harvest at all. In the northern tomato-growing sections defoliation diseases are by no means uncommon, but there they usually appear later in the season than farther South. The defoliation diseases as a group constitute one of the most serious hazards in tomato production for the greater part of the United States.

One of the original projects on the program of the United States Regional Vegetable Breeding Laboratory (organized in 1936 at Charleston, S. C.) was development of tomato varieties resistant to defoliation. As a first step in the project, an attempt was made to evaluate the several different causes of defoliation in the

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[2] The work of Hans Jorgensen, assistant scientific aide, Jack Eades, agent, and Margaret Kanapaux, junior physiologist Division of Fruit and Vegetable Crops and Diseases, Bureau of Plant Industry, in growing and handling the plants and in compilation of data, has greatly facilitated this study.

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Southeastern States. It seemed necessary to consider the possible role of nematodes, viruses, and physiological disorders related to unbalanced nutrition as well as of leaf spot fungi; these last were presumed to be the primary and most important cause of defoliation. The evaluation of different causes of tomato defoliation is still incomplete; but at this time it is possible to state that, of the leaf parasites, *Alternaria solani* (Ell. and Mart.) Jones and Grout, which causes early blight,[3] and *Stemphylium solani* Weber (*8*),[4] which causes gray leaf spot, are predominant in the area in which these investigations are being made. This circular deals exclusively, therefore, with the results obtained in breeding for resistance to *A. solani* and *S. solani* and the methods used in obtaining them. Included are the results of a survey of some domestic and introduced tomato varieties and species with respect to their relative tolerance to the two above-named organisms and of a breeding analysis of some interspecific and intervarietal crosses.

FIELD OBSERVATIONS ON TOMATO LEAF SPOTS FROM 1936 TO 1940

Tomato defoliation has occurred to a devastating extent in field plots of the United States Regional Vegetable Breeding Laboratory every summer since these investigations were begun; the details of the leaf spot picture, however, have changed slightly from year to year. In 1936 and 1937 much of the leaf spot was diagnosed as caused by *Septoria lycopersici* Speg., but microscopic and cultural studies on the fungus flora of tomato leaves were not begun until 1938; subsequently no *Septoria* has been observed.

In 1938 early blight, caused by *Alternaria solani*, was the predominant foliage disease, and it has ever since been an important cause of tomato defoliation in the experimental plots. Also in 1938, a comparatively new tomato disease, gray leaf spot, caused by *Stemphylium solani*, previously reported in Florida (*7*, *8*, *9*), occurred to a significant extent in the Charleston area. What is probably the same disease was reported from localities in Georgia in 1936.[5] In 1939 gray leaf spot was equal in importance to early blight, and in 1940 most of the extremely rapid defoliation that occurred after the first picking was due to the gray leaf spot organism. The relative prevalence of these diseases from 1938 to 1940 was estimated from hundreds of isolations from leaf spots. It can be understood, therefore, why the tomato-breeding project has been directed principally toward introduction of resistance to early blight and gray leaf spot.

Many other organisms have been isolated from tomato leaves; some of them have been proved to be pathogenic. They include species of *Mycosphaerella*, *Fusarium*, *Phyllosticta*, *Colletotrichum*, *Helminthosporium*, and small-spored species of *Alternaria*. The possibility of interrelationship of some of these organisms with the predominant *Alternaria solani* and *Stemphylium solani* will provide a promising field of future research. Eventually the breeding project

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[3] In conformity with the Division of Mycology and Disease Survey, Bureau of Plant Industry, the writers have accepted the interpretation of the genera *Alternaria* and *Macrosporium* by Wiltshire (*10*).

[4] Italic numbers in parentheses refer to Literature Cited, p. 23.

[5] MILLER, J. H. TOMATO DISEASE NOTES FOR GEORGIA FOR 1936. U. S. Bur. Plant Indus., Plant Dis. Rptr. 20: 350–355. 1936. [Processed.]

will need to be expanded to include attempts to introduce resistance to other leaf diseases.

During the spring and summer of 1936 a small collection of tomatoes from W. S. Porte [6] and a few commercial varieties were grown, and observations were made on their tolerance to defoliation diseases and their ability to set fruit during hot, humid weather. Hardy plants selected from this planting and from an expanded planting in 1937 (including a large number of strains from the United States Department of Agriculture Cheyenne Horticultural Field Station) provided the foundation stocks from which the crosses discussed in this circular were derived.

The varieties and accessions were grown in the field in four randomized series of six plants each, and each series was graded on a scale of 0 to 5 as follows: 0, no defoliation; 1, very slight defoliation; 2, moderate defoliation; 3, severe defoliation; 4, extreme defoliation; and 5, complete defoliation. Complete gradings were made usually just before the first picking and at the time the last marketable fruits were on the vine. Grades of 0 were recorded only in the early grading; the more susceptible varieties became extremely defoliated soon after the first fruits were mature, and by the second grading plants of most varieties were in either grade 4 or 5.

Extensive defoliation usually begins after the fruit has begun to mature; this common observation has led many persons to associate defoliation with some physiological change that occurs in the tomato plant during fruit production. At this stage defoliation can progress with such extreme rapidity that a change in the appearance of the plants can be noted from one day to the next. In the Charleston, S. C., district the period of active defoliation is associated not only with the period of fruit maturation but also with a period of heavy summer rains, heavy nightly dews, and warm, humid days; also, defoliation occurs after a long period of gradual increase of leaf-parasite populations. During a period of 7 to 10 days plants in moderately good foliage would become completely defoliated. The proper evaluation of the different factors named is difficult; however, methods for measuring the relative pathogenicity of the leaf-inhabiting organisms and the relative tolerance of tomato varieties to them have been developed.

The early field selections were made on the basis of comparative defoliation regardless of what the agents of defoliation might be, since these were to a considerable extent unidentified. Outstanding promise of tolerance to defoliation diseases was first found in progenies from *Lycopersicon pimpinellifolium* (Jusl.) Mill. (received under the accession No. P. I.[7] 79532 and known as currant) from Peru; in Targinnie Red, a variety of *L. esculentum* Mill., from Australia; and to a lesser extent in certain strains of Marglobe and Fiaschello. The seed stocks received as P. I. 79532 and Targinnie Red at Charleston, S. C., proved to be heterogeneous, and at the time greenhouse inoculations were begun in 1940 there were on hand 18 single-plant selections of P. I. 79532 and 8 single-plant selections of Targinnie Red. The P. I. 79532 selections included fruit types that were not characteristic of *L. pimpinellifolium* but rather of *L. esculentum* var. *cerasiforme*

[6] Bureau of Plant Industry Station, Beltsville, Md.
[7] P. I. refers to the accession numbers of the Division of Plant Exploration and Introduction.

(Dun.) A. Gray. It included both red and yellow currant types. The Targinnie Red selections included both large- and small-fruited strains, suggesting that natural outcrossing had occurred at some time after they left their point of origin.

METHOD OF GREENHOUSE INOCULATION

Actual pathogenicity studies with *Alternaria* and *Stemphylium* were not begun until 1940. The first problem in making inoculations with leaf spot fungi was to obtain sufficient quantities of conidia or spores to carry out large-scale inoculations and at the same time to obtain a high level of infection. Both *Alternaria solani* and *Stemphylium solani* produce conidia rather sparingly in pure culture. With special cultural techniques (*3*, *6*) they can be made to produce conidia more

FIGURE 1.—Tomato plants in greenhouse after preliminary inoculation with *A*, *Alternaria solani; B*, *Stemphylium solani;* and *C*, sterile culture medium.

abundantly but still not in the great quantities required for mass inoculations. It was decided, therefore, to dispense with conidia and to use vegetative parts of the fungus growth as infective particles. Although the customary procedure in making leaf spot inoculations is to spray the inoculum on the foliage, it was found that less processing of the cultures was required if the foliage was dipped in the inoculum.

Liquid cultures [8] of *Alternaria* and *Stemphylium* were macerated with a small electric stirrer, and 4-week-old potted tomato plants were inverted and the leaves dipped in the liquid inoculum. The plants used were from F_3 families of a Marglobe × *Lycopersicon pimpinellifolium* cross, together with representatives of each parent and a few commercial varieties. Inoculated plants were held over night in glass-topped humidity chambers and then removed to an open bench. The preliminary inoculations by this method proved to be highly

[8] The liquid media consisted of magnesium sulfate, 0.25 gm.; monopotassium phosphate, 0.5 gm.; peptone, 10 gm.; sucrose, 20 gm.; and distilled water, 1,000 cc.

successful (fig. 1). Extreme debility of susceptible plants was apparent 48 hours after inoculation. In the case of *Stemphylium* inoculations a clear-cut segregation of resistant and susceptible plants occurred (fig. 2).

The general procedure described was adopted for large-scale greenhouse inoculations. Among necessary modifications was dilution

FIGURE 2.—Plants inoculated with *Stemphylium* arranged by family or variety after grading and removal from randomized series.

of the inoculum to a point where the infection level would not be too high. It was found that too rich an inoculum would destroy even the most resistant plants included in the test (fig. 3), but that with a suitably diluted inoculum several grades of tolerance to each organism were distinguishable. Also it was found that preparation of inoculum could be facilitated by use of a high-speed mechanical liquefier (*1*) instead of the simple stirring device first employed; in less than 5

minutes the mechanical mixer reduced cultures to a degree of fineness not obtained in hours of stirring by the simpler machine.

The procedure finally used for making greenhouse inoculations was as follows: The tomato varieties, strains, or families were planted in groups of 40 each. They were seeded in flats and after 10 days were transplanted to 4-inch pots of soil, 3 plants per pot. Each variety was represented in 6 randomized series, 1 pot of 3 plants constituting a unit. The series were duplicated for *Alternaria* and *Stemphylium*, and with an additional check pot there were 13 pots and 39 plants for each variety. During inoculation the pots were handled in flats holding 18 each. Plants were inoculated 15 to 20 days after transplanting. The humidity chambers were able to accommodate only about 300 pots; therefore the *Stemphylium* and *Alternaria* inoculations

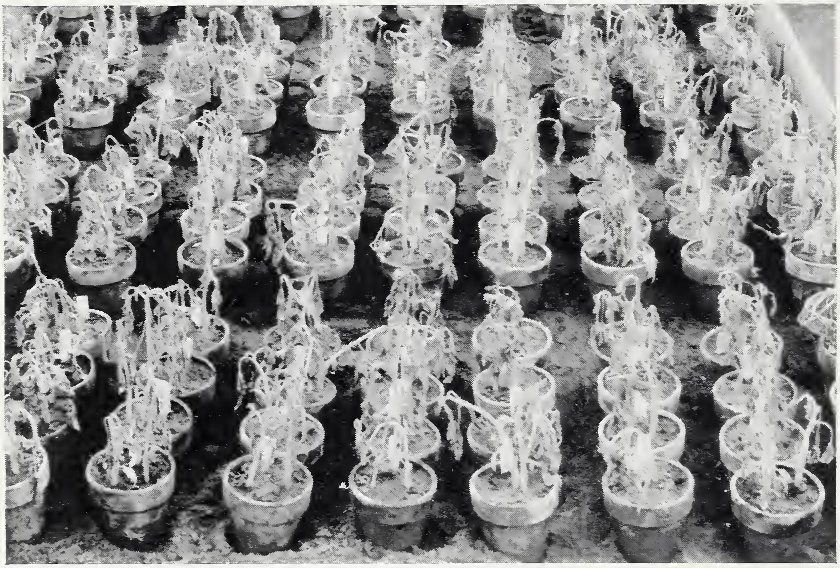

Figure 3.—Complete killing of plants by concentrated *Alternaria* inoculum. (Photographed 48 hours after treatment.)

were made on separate days. Sterilization of the chambers proved to be unnecessary. Check plants never became infected except for very infrequent single lesions. One set of checks sufficed for both organisms.

The inoculum was prepared from 15-day-old to 20-day-old liquid cultures incubated at 28° C. The inoculation of 720 plants with *Alternaria* required 2,400 cc. of culture and with *Stemphylium* 3,200 cc., the difference being due to the relatively greater virulence of the *Alternaria* under the conditions of experimentation. The cultures were treated 1½ minutes in the mechanical liquefier (blender) after which the quantity was divided into two parts, one to be diluted and the other to remain undiluted. The part to be diluted (1,200 cc. of *Alternaria* or 2,000 cc. of *Stemphylium*) was increased to 7 liters with distilled water. After dilution the 7 liters of inoculum was divided into six equal parts. The final inoculum consisted of about 1,200 cc. of diluted and 200 cc. of undiluted processed culture for each of the six series of plants to be inoculated.

In each series there were usually 120 plants. The first plants dipped in the inoculum had a tendency to screen out the richer part of the inoculum so that later plants would receive a lighter dosage. The undiluted inoculum therefore was used as a replenisher; approximately 30 cc. was added after every eighteenth plant.

Inoculated plants were kept two nights in the humidity chambers, because it had been found possible to economize on media by using a more dilute inoculum and leaving plants for a longer period in the chambers. Plants were removed from the chambers to open benches.

The effect of the inoculation was determined 1 week after inoculation. The following system of grading was used: 0, no lesion or other symptom of injury; 1, occasional lesion usually on the cotyledons; 2, lesions general but injury slight to moderate; 3, lesions numerous and some leaves killed; 4, defoliation complete except for terminal bud; and 5, plants dead (fig. 4). Each plant received a score, and the summation of scores for 18 plants in the 6 series was used in the estimate of relative resistance to the pathogen under

FIGURE 4.—Grades of injury following inoculation: *A*, Grade 1 (occasional lesion, usually on the cotyledons); *B*, grade 2 (lesions general, but injury slight to moderate); *C*, grade 3 (lesions numerous and some leaves killed); *D*, grade 4 (defoliation complete except for terminal bud); and *E*, grade 5 (dead).

examination. Scores ranging from 0 to 90 might be obtained for the different series, low scores indicating resistance and high scores susceptibility.

The adequacy of the technique described was amply supported by statistical analyses that were made of every replicated inoculation. The data were reduced by variance analysis in all cases. Where a plant was missing the total reported for the plot was obtained by averaging the remaining plots and adding this value to that for the other two plants in the pot to obtain a comparable total. In a few cases missing values for plots were calculated and a corresponding reduction was made in the number of degrees of freedom for error.

Individual plants showing an outstanding degree of tolerance to *Alternaria* or *Stemphylium* in the greenhouse test were selected for propagation in the field. Cuttings were made in February and March, and the resistant clones were transplanted to the field in April. Complete data on plant and fruit characters of each clone were taken in the field, and selections for future breeding were made on the basis of field observations and greenhouse inoculations combined. In some cases individual plant selections were transplanted to ground beds in the greenhouse, grown to maturity, and hybridized with other tomatoes. The greenhouse inoculations thus aided in speeding up the tomato-breeding project.

RESULTS OF ALTERNARIA AND STEMPHYLIUM INOCULATIONS

Interspecific and Intervarietal Hybrids

The most outstanding degree of leaf spot tolerance observed in the early field studies (p. 3) occurred in selections from P. I. 79532 (*L. pimpinellifolium*), and therefore the first greenhouse inoculations were concentrated on these selections and on hybrids obtained by crossing P. I. 79532 with Marglobe. Subsequently, representatives from 2 intervarietal crosses were tested, making a total of 328 families:

Currant (P. I. 79532) × Marglobe and reciprocal	181 families
Fiaschello × Marglobe and reciprocal	100 families
Marglobe × Resista	47 families

A few tolerant selections were made from the plants produced by the second and third crosses, but only the currant × Marglobe crosses showed clear-cut segregation of resistant and susceptible families. Therefore only these crosses will be dealt with in detail.

Hybrids from the currant × Marglobe cross were available in the form of 95 F_3 and 86 F_4 single-plant field selections made in 1939 and 1940, and a large quantity of the original F_2 seed was also available. About one-third of the field selections were made on the basis of leaf spot resistance, and the remainder on the basis of other plant and fruit characters.

Although parallel inoculations were made with *Alternaria* and *Stemphylium*, in some cases the reactions to the former were too severe to allow analysis, as all the lines were killed or severely damaged. This accounts for the differences in population sizes evident in some cases (fig. 5, *A–F*).

Complete freedom from the two defoliation diseases was not found in any tomato line. Of over 20,000 individual plants inoculated and graded, only 5 were given readings of 0, indicating freedom from any symptoms of the diseases at the time of reading. The scores (p. 7) are presented as frequency distributions with class intervals of 10 each. In this study the term "resistant" indicates only slight injury or partial freedom from leaf spot in contrast with plants found to be fully susceptible.

One of the first apparent facts is the difference in reaction to the two diseases among the hybrids involving P. I. 79532, there being fewer progenies segregating for resistance to *Alternaria* (fig. 5, *A*) than to *Stemphylium* (fig. 5, *B*). Of 108 progenies (fig. 5, *A* and *C*) inoculated with *Alternaria* 70, or 65 percent, were in the 81–90 class, indicating uniform high susceptibility, while of 181 progenies inoculated with *Stemphylium*, only 30, or 17 percent, were in this class (fig. 5, *B* and *D*). Of the progenies appearing homogeneous in their reaction to inoculation (uniformly resistant or susceptible) it will be seen that inoculation with *Alternaria* showed the great majority to be susceptible (fig. 5, *C*), whereas the *Stemphylium* inoculation revealed a more nearly equal distribution of resistant and susceptible progenies and a definite basis for separation of the former from the latter. Thus of the 83 progenies appearing in this group (fig. 5, *D*), 38 had scores ranging from 18 to 48 (considered resistant), 45 had scores ranging from 61 to 90 (considered susceptible), and none had scores between 48 and 61.

During the summer of 1940, 59 single-plant selections made in the field from the hybrid progenies were noted as being resistant to *Stemphylium*, as other plants surrounding them were infected by *Stemphylium* to varying degrees while the selections were essentially free of infection. As is shown in figure 5, *F*, the majority of these selected progenies showed some resistance to *Stemphylium* in the

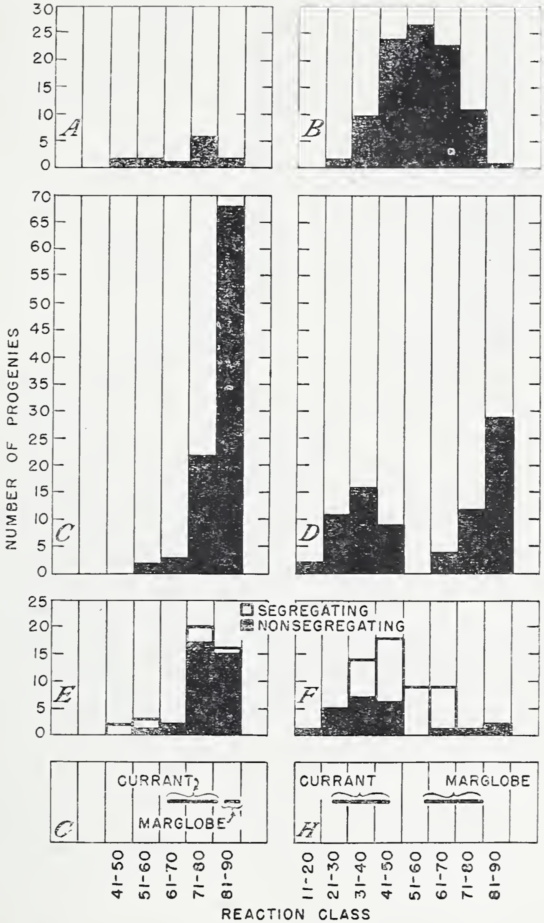

FIGURE 5.—Reaction of currant (P. I. 79532), Marglobe, and their hybrids to inoculation with *Alternaria solani* (*A*, *C*, *E*, *G*) and *Stemphylium solani* (*B*, *D*, *F*, *H*): *A* and *B*, F_3 and F_4 segregating progenies; *C* and *D*, F_3 and F_4 nonsegregating progenies; *E* and *F*, F_3 and F_4 progenies selected in the field for resistance to *Stemphylium;* *G* and *H*, parent lines.

inoculations in the greenhouse. Of the 23 nonsegregating progenies selected, 19 had *Stemphylium* scores indicating resistance (below 51) and only 4 had scores above 60, indicating susceptibility.

Of the 59 progenies from the plants selected in the field for resistance to *Stemphylium*, 43 were inoculated with *Alternaria*. Thirty-six of

these received scores indicating susceptibility, while 7 were in the three lowest classes suggesting tolerance (fig. 5, *E*). Six of these also had low *Stemphylium* scores, 50, 46, 35, 32, 19, and 18, the last named receiving the lowest reading observed for any one progeny or variety throughout the whole study. This was in an F_3 progeny from the currant × Marglobe cross.

The parents of the progenies discussed were included in each inoculation; the range of their reactions shows that in the inoculation with *Alternaria* a few of the progenies in the 41–50 and 51–60 classes (fig. 5, *A* and *C*) indicated more resistance than either parent (fig. 5, *G*). In the inoculation with *Stemphylium*, P. I. 79532, referred to as the currant parent, showed marked resistance and the Marglobe showed marked susceptibility (fig. 5, *H*). It will be seen also that the segregating progenies (fig. 5, *B*) have a range of reactions essentially the same as that of the parents, whereas in the nonsegregating group (fig. 5, *D*) the scores of the resistant progenies range about the same as the resistant currant parent and those of the susceptible progenies have a range approximating that of the Marglobe parent.

Varieties and Accessions

Commercial varieties were predominantly highly susceptible to both *Alternaria* and *Stemphylium* (fig. 6, *A* and *B*). Significant differences were discernible, however, when the infection level was kept relatively low by using a diluted inoculum (p. 5). An indication of the relative susceptibility of the varieties and accessions is recorded in tables 1 and 2. The data represent separate series of inoculations, and although differences in level of infection are apparent between inoculations made at different times, significant varietal differences occur in all. Even when all precautions are observed, variations in infection level are still a source of considerable error, and the ranking of varieties in tables 1 and 2 should not be accepted as completely accurate.

Among the scores recorded for varieties (table 1) it will be seen that the lowest after *Alternaria* inoculation are recorded in test No. 7, in which the plants were sprayed with the inoculum instead of being immersed. Bonny Best (243) scored 60 in this test and ranged from 81 to 89 in the other six. Marglobe selection (9–01) scored 62 in the sprayed treatment and ranged from 73 to 90 in the remaining *Alternaria* inoculations. With the exceptions of the scores made in test No. 7, no commercial variety had an *Alternaria* score below 60. Slightly more tolerant to *Alternaria* than the majority were the varieties King George, Danish Extra Early, Devon Surprize, and some sister lines of Pan America (table 1, tests 7 and 9).

Included in the varieties were 27 bulk and 8 single-plant selections from Targinnie Red, typically a medium-sized, late tomato, which has proved to be variable in form in trials at Charleston, S. C. In fact, cherry- and currant-fruited types appeared in some of the plantings. The 2 lines represented in classes 21–30 and 31–40 from *Stemphylium* inoculation (fig. 6, *B*) are both small-fruited Targinnie Red selections. Two of the seven lines in the 31–40 and 41–50 classes from *Alternaria* inoculation (fig. 6, *A*) are also small-fruited Targinnie Red selections.

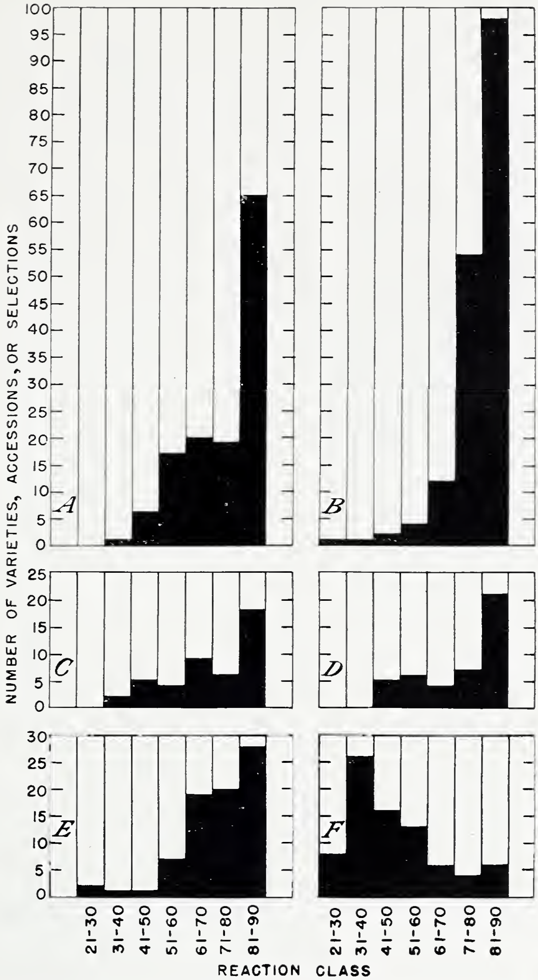

FIGURE 6.—Reaction of varieties, accessions, and selections to inoculation with *Alternaria solani* (*A*, *C*, *E*) and *Stemphylium solani* (*B*, *D*, *F*): *A* and *B*, Varieties; *C* and *D*, P. I. accessions; *E* and *F*, selections from P. I. No. 79532.

TABLE 1.—*Results of inoculating 1-month-old tomato plants with Alternaria in the greenhouse*

Test No. and Vegetable Breeding Laboratory accession No.	Strain or variety	Score [1]
Test No. 7: [2]		
7-01	P. I. 79532 selection.	26
781	Cherry	28
606	P. I. 115214	34
8-03	P. I. 79532 selection.	35
543	P. I. 128651	36
207	King George	40
6-02	Targinnie Red selection.	44
6	do	44
624	U. S. 23W (b20) [3]	44
518	P. I. 126938	45
555	P. I. 128654	46
35	Devon Surprize	47
621	U. S. 16W (b20) [3]	47
545	P. I. 128653	48
30	Danish Extra Early.	49
625	U. S. 23W (e1) [3]	51
231	Louisiana Gulf State (20-5).	54
623	U. S. 23W (a20) [3]	54
620	U. S. 16W (a6) [3]	54
195	Indiana Certified Marglobe.	56
618	U. S. 7W (c20) [3]	56
217	Marvel	56
38	Earliest of All	57
29	Danmark	58
56	Fiaschello	58
619	U. S. 7W (d5) [3]	59
887	Summerset strain (B1-5-1).	60
570	Everbearing	60
243	Bonny Best	60
571	Bay State	61
228	Master Marglobe	61
10-02	Commercial Marglobe selection.	62
622	U. S. 16W (c1) [3]	62
192	Pritchard	62
9-01	Marglobe selection.	62
200	Rutgers	64
9-04	Marglobe selection.	66
199	Indiana Certified Baltimore.	70
Statistical constants:		
Standard deviation $\sqrt{6}$.		3.51
Difference required for significance at 5-percent point.		9.79
Difference required for significance at 1-percent point.		12.90
Correlation between *Alternaria* and *Stemphylium* scores.		.7027**
Test No. 8:		
44	Currant	53
34	Cereza	54
13	Adelaide Dwarf	60
55	Earliest Open Ground.	60
Test No. 8—Con.		
30	Danish Extra Early.	62
31	Danish Export	65
6-02-5	Targinnie Red selection.	69
45	Dobbies Champion.	70
50	Currant	70
40	Early Ficarazzi	72
54	Erste Ernte	72
52	Essex Wonder	73
57	Johannisfeuer	78
58	In Miscuglio	82
16	Chemin Early Red.	85
24	Cameron Canada	85
21	Burwood Prize	86
47	Helvetia	87
46	Gelbfleischiger	87
56	Fiaschello	88
49	Fruhwonder	88
20	Bides Recruit	88
12	Antibes	88
9-01	Marglobe selection.[3]	
59	Il Duce [4]	88
42	Dukkers	89
17	Beauty of Loraine.	89
243	Bonny Best	89
23	Augusta	89
51	Export	89
48	Holmes Supreme	90
27	Des Allies	90
22	Bowen Buckeye	90
Statistical constants:		
Standard deviation $\sqrt{6}$.		3.18
Difference required for significance at 5-percent point.		8.89
Difference required for significance at 1-percent point.		11.74
Correlation between *Alternaria* and *Stemphylium* scores.		.395*
Test No. 10:		
128	Currant	45
170	P. I. 105267	57
156	P. I. 102716	66
161	P. I. 109315	67
123	Phenomen	67
6-02-5	Targinnie Red selection.	68
121	Queen Mary	69
152	P. I. 95590	76
154	Unidentified	83
159	P. I. 95592	83
166	P. I. 109834	83
134	P. I. 102725	84
126	Pera	85
125	Pfitzers Schone v. Lothringen.	85
127	Rouge grosse hâtive.	86
129	Pierrette Precocissimo.	86

See footnotes at end of table.

TABLE 1.—*Results of inoculating 1-month-old tomato plants with Alternaria in the greenhouse*—Continued

Test No. and Vegetable Breeding Laboratory accession No.	Strain or variety	Score [1]	Test No. and Vegetable Breeding Laboratory accession No.	Strain or variety	Score [1]
Test No. 10—Con.			Test No. 11—Con.		
132	Ham Green Favourite.	86	222	Gulf State Market.	88
168	P. I. 105342	88	228	Master Marglobe	88
243	Bonny Best	88	576	Currant × Marglobe (F_3).	88
122	Pierrette	88	387	P. I. 126920	90
130	Rosso Precocissimo.	88	433	P. I. 128602	90
136	P. I. 102717	88	Statistical constants:		
145	P. I. 92853	88	Standard deviation $\sqrt{6}$.		5. 15
149	P. I. 92857	88	Difference required for significance at 5-percent point.		14. 37
177	P. I. 95586	88	Difference required for significance at 1-percent point.		18. 97
133	Rosenborg	89	Correlation between *Alternaria* and *Stemphylium* scores.		. 707**
9–01	Marglobe selection.	90	Test No. 12:		
117	Pilot	90	8–016	P. I. 79532 selection.	63
131	Goldball	90	6–06–5	Targinnie Red selection.	82
153	P. I. 95589	90	8–013	P. I. 79532 selection.	82
155	P. I. 102715	90	973	Riverside	83
167	P. I. 109512	90	6–09–1	Targinnie Red selection.	83
172	P. I. 103055	90	6–02–2	do	83
176	P. I. 109514–B	90	8–018	P. I. 79532 selection.	84
Statistical constants:			8–010	do	84
Standard deviation $\sqrt{6}$.		2. 94	6–4	Targinnie Red selection.	85
Difference required for significance at 5-percent point.		8. 21	8–012–1	P. I. 79532 selection.	85
Difference required for significance at 1-percent point.		10. 84	8–15	do	86
Correlation between *Alternaria* and *Stemphylium* scores.		. 448*	8–14	do	86
Test No. 11:			8–09–12	do	86
504	Currant	47	8–017	do	86
384	P. I. 126913	49	970	Vetomold	86
509	P. I. 126437	49	974	Marhio	86
508	P. I. 126436	54	8–09–4	P. I. 79532 selection.	87
512	P. I. 126927	54	6–08–1	Targinnie Red selection.	87
289	P. I. 128174	58	8–04	P. I. 79532 selection.	87
506	P. I. 126432	61	8–015	do	87
666	P. I. 129042	62	8–021	do	87
655	P. I. 129027	62	6–06–4	Targinnie Red selection.	88
600	P. I. 115199	63	6–04–1	do	88
30	Danish Extra Early.	63	243	Bonny Best	88
511	P. I. 126924	64	889	Pan America	88
505	P. I. 126430	65	9–01	Marglobe selection.	88
575	Currant × Marglobe (F_3).	65	6–010	Targinnie Red selection.	89
8–03	P. I. 79532 selection.	66	10–02	Commercial Marglobe selection.	96
540	P. I. 128648	69	8–09–3	P. I. 79532 selection.	89
272	P. I. 126428	71	8–09–11	do	89
118	Original Pomona	74	975	Globelle	89
507	P. I. 126433	74	890	Essar	90
614	P. I. 115871	78			
291	P. I. 128177	79			
334	P. I. 128609	79			
72	Novato	80			
24	Cameron Canada	81			
223	Cooper Special	82			
243	Bonny Best	84			
234	Montgomery	85			
320	P. I. 128447	85			
774	P. I. 131877	86			
9–01	Marglobe selection.	86			

See footnotes at end of table.

TABLE 1.—*Results of inoculating 1-month-old tomato plants with Alternaria in the greenhouse*—Continued

Test No. and Vegetable Breeding Laboratory accession No.	Strain or variety	Score [1]
Test No. 12—Con.		
244-0-1-4	Currant × Marglobe (F_4).	90
8-16	P. I. 79532 selection.	90
8-17	do	90
8-18	do	90
887	Summerset strain (B1-5-1).	90
Statistical constants:[5]		
Correlation between *Alternaria* and *Stemphylium* scores.		.856**
Test No. 13:		
8-06-1	P. I. 79532 selection.	42
8-07-1	do	51
7-013-2	do	52
8-02A-1	do	53
7-02-1	do	58
7-02-4	do	60
7-013-4	do	60
8-2	do	60
7-07-1	do	61
7-013-5	do	61
8-09-1	do	61
7-013-1	do	62
8-8	do	62
8-02A-2	do	62
8-08-2	do	62
7-010-3	do	63
8-010	do	63
7-04-1	do	64
8-03-1	do	64
7-0-11-1	do	65
8-02A	do	65
8-05-2	do	65
8	do	68
7-0-10-1	do	69
8-05-3	do	71
8-012	do	71
6-02-2	Targinnie Red selection.	72
8-4	P. I. 79532 selection.	72
8-12	do	73
8-03-2	do	73
9-01	Marglobe selection.	73
7-06-1	P. I. 79532 selection.	74
8-1	do	74
8-3	do	75
8-7	do	76
8-11	do	76
7-0-10-2	do	77
8-13	do	77
7-012-1	do	78
8-5	do	79
230	Dixie	79
7-013-3	P. I. 79532 selection.	80
8-6	do	80
243	Bonny Best	81
8-09-2	P. I. 79532 selection.	82
8-9	do	83
8-10	do	84
Test No. 13—Con.		
8-05-4	P. I. 79532 selection.	87
Statistical constants:		
Standard deviation $\sqrt{6}$.		6.39
Difference required for significance at 5-percent point.		17.82
Difference required for significance at 1-percent point.		23.49
Correlation between *Alternaria* and *Stemphylium* scores using all lines.		.154
Correlation between *Alternaria* and *Stemphylium* scores using lines with *Alternaria* scores below 70.		.556*
Test No. 14:		
6-10	Targinnie Red selection.	67
8-03	P. I. 79532 selection.	70
6-06-3	Targinnie Red selection.	70
6-8	do	71
6-02-8	do	72
8-09-8	P. I. 79532 selection.	73
7-013-7	do	73
7-04-2	do	73
6-02-2	Targinnie Red selection.	77
6-7	do	77
6-03-2	do	78
6-9	do	79
6-02-3	do	80
6-03-1	do	80
6-06-6	do	80
8-09-10	P. I. 79532 selection.	80
6-08-2	Targinnie Red selection.	81
8-09-9	P. I. 79532 selection.	81
7-013-9	do	82
8-09-7	do	82
6-02-4	Targinnie Red selection.	83
6-2	do	83
6-3	do	83
243	Bonny Best	84
9-01	Marglobe selection.	86
6-6	Targinnie Red selection.	87

See footnotes at end of table.

TABLE 1.—*Results of inoculating 1-month-old tomato plants with Alternaria in the greenhouse*—Continued

Test No. and Vegetable Breeding Laboratory accession No.	Strain or variety	Score [1]
Test No. 14—Con.		
7-01-2-2	P. I. 79532 selection.	88
8-09-2	do	88
8-09-7	do	88
8-16	do	90
8-09-5	do	90
Statistical constants:		
Standard deviation $\sqrt{6}$.		5.81
Difference required for significance at 5-percent point.		11.48
Difference required for significance at 1-percent point.		15.16
Correlation between *Alternaria* and *Stemphylium* scores.		.035

[1] Score is sum of readings for 18 plants (see p. 7). *=Significant at 5-percent point; **=significant at 1-percent point.
[2] Plants sprayed instead of immersed.
[3] Sister line of Pan America from W. S. Porte.
[4] Probably not true to type.
[5] See text; standard error and differences required for significance not computed.

TABLE 2.—*Results of inoculating 1-month-old tomato plants with Stemphylium in the greenhouse*

Test No. and Vegetable Breeding Laboratory accession No.	Strain or variety	Score [1]
Test No. 7: [2]		
7-01	P. I. 79532 selection.	33
8-03	do	39
606	P. I. 115214	45
624	U. S. 23W (b20)[3]	46
518	P. I. 126938	50
620	U. S. 16W (a6)[3]	51
621	U. S. 16W (b20)[3]	52
625	U. S. 23W (e1)[3]	53
30	Danish Extra Early.	55
543	P. I. 128651	59
555	P. I. 128654	61
9-04	Marglobe selection	62
6-02	Targinnie Red selection.	63
192	Pritchard	65
781	Cherry	65
9-01	Marglobe selection.	65
6	Targinnie Red selection.	66
35	Devon Surprize	67
207	King George	68
619	U. S. 7W (d5)[3]	70
56	Fiaschello	71
622	U. S. 16W (c1)[3]	72
217	Marvel	72
200	Rutgers	73
545	P. I. 128653	73
570	Everbearing	73
618	U. S. 7W (c20)[3]	75
38	Earliest of All	76
887	Summerset strain (B1-5-1).	77
195	Indiana Certified Marglobe.	78
29	Danmark	78
243	Bonny Best	81
Test No. 7—Con.		
231	Louisiana Gulf State.	82
10-02	Commercial Marglobe selection.	82
623	U. S. 23W (a20)[3]	82
228	Master Marglobe	83
571	Bay State	84
199	Indiana Certified Baltimore.	88
Statistical constants:		
Standard deviation $\sqrt{6}$.		4.70
Difference required for significance at 5-percent point.		13.2
Difference required for significance at 1-percent point.		17.3
Test No. 8:		
44	Currant	42
59	Il Duce [4]	44
50	Currant	48
34	Cereza	65
54	Erste Ernte	76
24	Cameron Canada	76
58	In Miscuglio	76
45	Dobbies Champion.	77
52	Essex Wonder	78
13	Adelaide Dwarf	78
6-02-5	Targinnie Red selection.	78
9-01	Marglobe selection.	78

See footnotes at end of table.

TABLE 2.—*Results of inoculating 1-month-old tomato plants with Stemphylium in the greenhouse*—Continued

Test No. and Vegetable Breeding Laboratory accession No.	Strain or variety	Score [1]
Test No. 8—Con.		
22	Bowen Buckeye	80
17	Beauty of Lorraine.	80
37	El Colono	81
49	Fruhwonder	81
31	Danish Export	83
30	Danish Extra Early.	83
23	Augusta	83
12	Antibes	83
47	Helvetia	83
243	Bonny Best	84
32	Costato "Prima de Tutt."	85
57	Johannisfeuer	85
46	Gelbfleischiger	85
16	Chemin Early Red.	86
21	Burwood Prize	86
28	Dansk Export	86
43	Dobbies Holyrood.	86
26	Indefatigable	86
56	Fiaschello	87
48	Holmes Supreme	87
51	Export	87
40	Early Ficarazzi	87
55	Earliest Open Ground.	88
27	Des Allies	89
42	Dukkers	90
Statistical constants:		
Standard deviation $\sqrt{6}$.		2.92
Difference required for significance at 5-percent point.		8.14
Difference required for significance at 1-percent point.		10.74
Test No. 9: [5]		
8-03-1	P. I. 79532 selection.	40
93	Trivetts Abundance.	70
60	Golden Queen	72
61	Labrador	72
70	Gilbertiana	74
64	Heterosis	76
103	Wonder of Italy	76
69	Green Gage	78
91	Tuckswood	78
73	N. C. D. (Bides)	80
82	Laxtons Open Air	80
97	Soleil Levant	80
75	Marshalls Prolific.	82
89	Uberreich	82
99	Semperfructifera	82
6-02-5	Targinnie Red selection.	84
9-01	Marglobe selection.	84
62	King Humbert	84
80	Lucullus	84
88	Up-to-date	84
96	Standard	84
114	Radio	84
63	Rondine Red	86
Test No. 9—Con.		
76	Market Wonder	86
78	Magnum Bonum	86
107	Walkers Selected Recruit.	86
84	La Naine	88
102	Woodwards Sensation.	88
108	Victor Emanuel	88
243	Bonny Best	90
65	General Joffre	90
66	Goldkönigin	90
68	Amarillo	
71	Gnome	90
74	Mikado	90
81	Large Red	90
85	Riverside Favorite.	90
86	Kampioen	90
90	Tuckstir	90
101	Zwaans Serrerwonder.	90
Statistical constants:		
Standard deviation $\sqrt{6}$.		2.08
Difference required for significance at 5-percent point.		5.84
Difference required for significance at 1-percent point.		7.75
Test No. 10:		
9-01	Marglobe selection.	76
170	P. I. 105267	77
128	Currant	78
166	P. I. 109834	78
161	P. I. 109315	79
6-02-5	Targinnie Red selection.	80
117	Pilot	80
121	Queen Mary	82
122	Pierrette	82
177	P. I. 95586	82
132	Ham Green Favourite.	83
172	P. I. 103055	83
176	P. I. 109514-B	83
154	Unidentified	84
156	P. I. 102716	84
159	P. I. 95592	84
129	Pierrette Precocissimo.	85
130	Rosso Precocissimo.	85
145	P. I. 92853	85
152	P. I. 95590	85
160	P. I. 102719	85
168	P. I. 105342	85
125	Pfitzers Schone v. Lothringen.	86
127	Rouge grosse hâtive.	86
126	Pera	87
153	P. I. 95589	88
133	Rosenborg	88
243	Bonny Best	89
123	Phenomen	89
155	P. I. 102715	89
131	Goldball	90

See footnotes at end of table.

TABLE 2.—*Results of inoculating 1-month-old tomato plants with Stemphylium in the greenhouse*—Continued

Test No. and Vegetable Breeding Laboratory accession No.	Strain or variety	Score [1]
Test No. 10—Con.		
149	P. I. 92857	90
Statistical constants:		
Standard deviation $\sqrt{6}$.		2.44
Difference required for significance at 5-percent point.		6.81
Difference required for significance at 1-percent point.		8.99
Test No. 11:		
8-03	P. I	44
575	Currant × Marglobe (F_2).	48
507	P. I. 126433	49
505	P. I. 126430	49
509	P. I. 126437	50
540	P. I. 128648	51
512	P. I. 126927	52
508	P. I. 126436	53
655	P. I. 129027	57
510	P. I. 126923	58
576	Currant × Marglobe (F_3).	60
504	Currant	62
506	P. I. 126432	62
511	P. I. 126924	63
384	P. I. 126913	64
289	P. I. 128174	73
666	P. I. 129042	73
30	Danish Extra Early.	74
600	P. I. 115199	78
334	P. I. 128609	83
24	Cameron Canada	83
272	P. I. 126428	84
228	Master Marglobe	86
118	Original Pomona	87
9-01	Marglobe selection	87
72	Novato	87
774	P. I. 131877	88
291	P. I. 128177	88
35	Devon Surprize	88
320	P. I. 128447	88
614	P. I. 115871	89
243	Bonny Best	89
387	P. I. 126920	89
433	P. I. 128602	89
234	Montgomery	90
222	Gulf State Market	90
223	Cooper Special	90
Statistical constants:		
Standard deviation $\sqrt{6}$.		3.05
Difference required for significance at 5-percent point.		8.52
Difference required for significance at 1-percent point.		11.24
Test No. 12:		
244-0-1-4	Currant × Marglobe (F_4).	42
8-018	P. I. 79532 selection.	47
8-012-1	do	51
8-14	do	51
8-15	do	52
8-09-11	do	52
8-015	do	56
8-013	do	58
8-09-4	do	58
8-010	do	59
8-016	do	60
8-017	do	60
8-09-3	do	61
8-09-12	do	62
6-08-1	Targinnie Red selection.	63
8-16	P. I. 79532 selection.	64
8-17	do	64
8-18	do	64
6-06-4	Targinnie Red selection.	74
6-4	do	75
6-06-5	do	76
8-04	P. I. 79532 selection.	77
10-02	Commercial Marglobe selection.	78
6-04-1	Targinnie Red selection.	78
8-021	P. I. 79532 selection.	79
889	Pan America	79
973	Riverside	81
974	Marhio	81
6-02-2	Targinnie Red selection.	82
6-09-1	do	83
975	Globelle	84
9-01	Marglobe selection	85
6-010	Targinnie Red selection.	86
970	Vetomold	87
243	Bonny Best	87
890	Essar	88
887	Summerset strain (B1-5-1).	89
Statistical constants:		
Standard deviation $\sqrt{6}$.		4.07
Difference required for significance at 5-percent point.		11.35
Difference required for significance at 1-percent point.		14.98
Test No. 13:		
7-013-5	P. I. 79532 selection.	28
7-07-1	do	30
7-02-4	do	30
7-02-1	do	31
7-012-1	do	32

See footnotes at end of table.

Table 2.—*Results of inoculating 1-month-old tomato plants with Stemphylium in the the greenhouse*—Continued

Test No. and Vegetable Breeding Laboratory accession No.	Strain or variety	Score [1]
Test No. 13—Con.		
7-04-1	P. I. 79532 selection.	33
7-013-3	do	33
8-06-1	do	33
8-10	do	34
7-010-2	do	35
7-013-1	do	35
7-013-2	do	35
7-011-1	do	36
8-12	do	36
8-09-1	do	37
7-010-1	do	38
8-9	do	38
8-6	do	39
8-13	do	39
8-03-1	do	39
7-010-3	do	40
8-02A-1	do	41
8-03-2	do	42
8-08-2	do	42
8-2	do	43
8-4	do	43
8-5	do	43
8-7	do	43
8-11	do	43
8-02A	do	43
8-02A-2	do	44
8-3	do	45
8-012	do	46
8	do	47
8-05-3	do	51
8-09-2	do	55
8-1	do	56
8-010	do	70
7-06-01	do	79
7-013-4	do	82
9-01	Marglobe selection.	82
8-05-2	P. I. 79532 selection.	85
6-02-2	Targinnie Red selection.	86
8-8	P. I. 79532 selection.	86
8-07-1	do	86
8-05-4	do	87
230	Dixie	90
243	Bonny Best	90
Statistical constants:		
Standard deviation $\sqrt{6}$.		3.63
Difference required for significance at 5-percent point.		10.12
Difference required for significance at 1-percent point.		13.34
Test No. 14:		
8-09-7	P. I. 79532 selection.	21
8-09-8	do	23
6-02-2	Targinnie Red selection.	24
8-09-7	P. I. 79532 selection.	27
7-04-2	do	27
8-09-10	do	27
7-013-9	do	33
8-03	do	33
8-09-2	do	33
8-16	do	34
6-08-2	Targinnie Red selection.	35
8-09-5	P. I. 79532 selection.	38
8-09-9	do	45
6-06-6	Targinnie Red selection.	71
6-9	do	71
6-3	do	72
9-01	Marglobe selection.	73
6-6	Targinnie Red selection.	73
7-013-7	P. I. 79532 selection.	73
6-2	Targinnie Red selection.	74
6-03-1	do	77
243	Bonny Best	78
6-02-3	Targinnie Red selection.	78
6-02-4	do	78
6-06-3	do	78
6-02-8	do	79
6-03-2	do	80
6-8	do	80
6-10	do	81
7-01-22	P. I. 79532 selection.	82
6-011-1	Targinnie Red selection.	83
6-7	do	84
Statistical constants:		
Standard deviation $\sqrt{6}$.		3.37
Difference required for significance at 5-percent point.		9.41
Difference required for significance at 1-percent point.		12.43

[1] Score is sum of readings for 18 plants (see p. 7). See table 1 for correlation between *Alternaria* and *Stemphylium* scores.
[2] Plants sprayed instead of immersed.
[3] Sister line of Pan America from W. S. Porte.
[4] Probably not true to type.
[5] Only 3 series used, corrected values for 6 series.

Except for the few resistant individual plant selections, the controlled inoculations on Targinnie Red failed to confirm the field observation that the variety is resistant to defoliation. Many samples of Targinnie Red proved to be very susceptible to *Stemphylium* and displayed barely a significant degree of tolerance to leaf infection by *Alternaria*. It may be significant, however, that Targinnie Red typically shows resistance to stem infection by *Alternaria*.

Of a large number of tomato accessions received through the Division of Plant Exploration and Introduction, 44 in addition to P. I. 79532 have been tested up to this time. The different reactions of these lines are shown in figure 6, *C* and *D*. Among the accessions tested by inoculation with *Alternaria* were 14 currant tomatoes (*Lycopersicon pimpinellifolium*), 4 lines of *L. peruvianum* (L.) Mill. and *L. peruvianum* var. *dentatum* Dun., 3 cherry tomatoes (*L. esculentum* var. *cerasiforme*), and 23 large-fruited tomatoes (*L. esculentum*). Of the 7 lines in the 2 most resistant classes, 31–40 and 41–50 (fig. 6, *C*), only 1 of the *L. esculentum* type was represented, whereas in the 2 most susceptible classes, 71–80 and 81–90 (indicating susceptibility to *Alternaria*), 22 of 24 were of this type. On the other hand almost all the currant tomatoes were in the more resistant classes, 13 of 14 lines having scores below 66. All 4 of the *L. peruvianum* lines included had reactions between those of the currant and large-fruited types and in general showed considerable tolerance. One of the low scores (table 1, test 7, 781 with a score of 28) from inoculation with *Alternaria* was that recorded for a cherry tomato, which originated from plants growing as escapes near Cairo, Ga.

In the inoculations with *Stemphylium* much the same picture is presented (fig. 6, *D*). Of the 28 lines having scores above 70, that is, the more susceptible ones, 25 were *Lycopersicon esculentum*, and of the 15 lines having scores below 71, indicating tolerance, only 1 was a line of *L. esculentum*. The currant tomatoes were again decidedly more tolerant to the effects of inoculation, as 10 of the 15 in the classes below 71 were currants. One currant line received a score of 42 (table 2, test 8). With *Stemphylium* inoculation the cherry tomatoes and *L. peruvianum* tested scored from 51 to 73 and were again intermediate between commercial varieties and currant tomatoes in their reactions.

As mentioned previously, the material that came to this station as P. I. 79532 has shown some variation in plant and fruit types. In the course of 5 years of field trials many row and single-plant selections from this accession have been made. Seventy-nine of these have been tested in the inoculation with *Stemphylium* (fig. 6, *F*). It is evident that the majority of these lines show some resistance or tolerance to this organism, as more than half (50 out of 79) had scores below 51. However, in the inoculation with *Alternaria* (fig. 6, *E*) the majority were in the upper, more susceptible, classes. Although there is considerable variation in the fruit size, plant vigor, and growth habit, it cannot be stated that each line is different. Thus there is some duplication in the scoring of several essentially identical lines.

Slight differences in numerical rating of tolerance to *Alternaria* among varieties of *Lycopersicon esculentum* may prove to be very important, and judicious intercrosses among the most tolerant ones as well as with the more resistant *L. pimpinellifolium* lines may produce

results of real value. Hybrids of *L. pimpinellifolium* and several *L. esculentum* varieties in the F_1 and F_2 generations are available for analysis by the inoculation procedure. The tolerance shown in the few lines of *L. peruvianum* and its variety *dentatum* that have been tested suggest that in those and the 50 or more remaining lines some valuable resistance may be found. Attempts are being made to introduce this species into the breeding project.

Controlled inoculations of *Lycopersicon hirsutum* Humb. and Bonpl. are incomplete at this time, but field observations indicate that it is resistant to *Alternaria* and susceptible to *Stemphylium*. Hybrids of this species with several varieties of *L. esculentum* are being tested in the greenhouse and in the field.

In 13 of the tests in which *Alternaria* and *Stemphylium* inoculations were made on parallel samples from the same lines, correlations between the *Alternaria* and *Stemphylium* scores were calculated. The analyses revealed a positive correlation in tolerance in each test, but only 5 of the correlations were significant (table 1). The tendency of *Alternaria* scores to accumulate at the high end of the scale, due to severe inoculation, tends to mask a probably high correlation with *Stemphylium*. In test 13 (table 1) there is a nonsignificant correlation ($r=0.154$) in the calculations using all scores in the test and a significant correlation ($r=0.556$) in calculations disregarding the lines with *Alternaria* scores bunched between 70 and 90.

DISCUSSION

Previous studies on the control of tomato defoliation diseases have dealt with the application of fungicides and with the effect of fertilizers, particularly nitrate. Several observers have noted the occurrence of significant differences in tolerance to early blight and septoria leaf spot among commercial varieties of tomato, but apparently no data have been published. Gray leaf spot, caused by *Stemphylium*, although a less familiar disease, may become equal in importance to early blight and septoria leaf spot as a cause of tomato defoliation in the South; in Florida and South Carolina it is now probably the most important of the three causes of defoliation.

Weber et al. (*9*) observed no resistance to gray leaf spot among existing varieties of tomatoes, and no later studies of this organism have been published. The present investigations, initiating a study of many domestic and introduced varieties or strains of tomatoes, reveal significant degrees of tolerance to both early blight and gray leaf spot among commercial varieties and a high degree of resistance to gray leaf spot in certain selections of *Lycopersicon pimpinellifolium*.

Most freedom from leaf spotting so far observed in the field has been in connection with partial sterility or unfruitfulness, but there are several productive lines that are exceptions. Consequently in breeding for resistance to defoliation it is necessary to keep in mind always the objective of heavy-bearing plants, lest breeding for resistance might quickly result only in sorting out and saving unfruitful lines.

The inoculation technique outlined in this circular has proved to be of value in rapidly evaluating a large number of lines of tomatoes with regard to their leaf spot resistance. The validity of the method is indicated by the fact that lines selected in the field for *Stemphylium* resistance showed decidedly more resistance as measured by the

inoculations with *Stemphylium* than lines selected for other reasons. Of 59 hybrid progenies selected in the field for resistance to *Stemphylium*, only 3 had *Stemphylium* inoculation readings above 70; that is, in the definitely susceptible class.

Another feature of the method is that it subjects the plants to one organism only and eliminates many complicating factors found in the field plantings, such as presence of other leaf-inhabiting organisms, nematode injury, and wide soil variations. The inoculation studies will eventually be extended to include *Septoria* and any other leaf-inhabiting fungi that prove to be important agents of defoliation.

Since parallel inoculations were made with *Alternaria solani* and *Stemphylium solani*, the data provide an excellent opportunity for comparison of the two organisms in respect to symptomatology and virulence. One of the first observations to be noted was the more pronounced tendency of *Alternaria* to attack the stems as well as the leaves. Deep stem cankers, typical of early blight lesions in the field, were common on plants inoculated with *Alternaria*, whereas stem infections by *Stemphylium* occurred in the form of superficial lesions or failed to occur. The two parasites attacked leaves with about equal severity, and the leaf lesions were quite indistinguishable in appearance within the 7-day interval between inoculation and recording.

Another fact that would tend to indicate that resistance to stem lesions and resistance to leaf infection may be due to independent factors is that certain varieties may fail to develop stem lesions from inoculations with *Alternaria* even though the leaves are fully susceptible. Observations along this line have been made in a separate study of the collar rot phase of infection of tomatoes by *Alternaria*.

In field plantings it is a common observation that the older leaves are the first affected by early blight and the first to die. Although gray leaf spot in the field appears on young leaves quite as readily as on those more mature, the 1-month-old plants used in the inoculations in the greenhouse when inoculated with either *Alternaria* or *Stemphylium* showed the first killing on the lower leaves. These were of course no more than 2 or 3 weeks older than the youngest leaves. The greenhouse observations indicate that very young tomato leaves have a type or degree of resistance not possessed by older leaves.

In the present study the most outstanding resistance to *Stemphylium* was found in lines of *Lycopersicon pimpinellifolium*, particularly in P. I. 79532 and hybrids involving this tomato as a parent. It is from this same accession that fusarium wilt resistance was introduced by Porte and Walker (*4*), Porte and Wellman (*5*), and Bohn and Tucker (*2*) into hybrids with commercial varieties. Some lines of hybrids with Marglobe (U. S. 16W and U. S. 23W), sister lines of Pan America developed by Porte and Walker (*4*) for fusarium wilt resistance, have shown some tolerance to *Stemphylium* and *Alternaria* in inoculation tests. On the other hand, Pan America has exhibited susceptibility to *Stemphylium* and *Alternaria*, as determined by inoculations. It may be possible with the materials on hand to determine the relationships, if any, of resistance to fusarium wilt and the leaf spot diseases under consideration.

From the information thus far obtained it seems definitely established that factors for resistance to *Stemphylium* and *Alternaria* are present in the materials examined, but the mode of inheritance and number of factors involved have not been determined. Over 100 F_3

and F_4 populations inoculated with *Stemphylium* showed unmistakable segregation, and 75 F_3 and F_4 populations examined showed nearly uniform resistance or susceptibility.

Some preliminary inoculations of F_2 progenies are being made, and it appears that essentially the same range of reactions is being obtained as with the F_3 and F_4 progenies. There are indications that resistance is dominant over susceptibility. The F_3 and F_4 progenies used in this study were not derived from a random selection from F_2 plants but were field-selected for a variety of characters, thus introducing bias into the study. An evaluation of the mode of inheritance must await analysis of F_3 progenies especially grown for genetic tests.

At present approximately 200 introductions and varieties out of more than 1,000 available have been tested under controlled conditions by the inoculation technique for resistance to early blight and gray leaf spot. These include a large number of introductions from foreign countries and contain lines of *Lycopersicon esculentum*, *L. esculentum* var. *cerasiforme*, *L. esculentum* f. *pyriforme*, *L. pimpinellifolium*, and several of the green-fruited species. Only a few of the last-named group have been tested, but among these there are indications of tolerance to both diseases.

SUMMARY

This circular covers the preliminary results of an extended breeding project planned to develop tomatoes resistant to defoliation diseases. The methods described include the field grading of a large number of hybrid populations, commercial varieties, and foreign introductions. An efficient inoculation technique, involving the use of finely cut mycelium, for testing large numbers of plants under controlled greenhouse conditions for resistance to early blight, caused by *Alternaria solani*, and gray leaf spot, caused by *Stemphylium solani*, was developed and used.

All varieties proved to be susceptible to early blight whenever the infection level was sufficiently high. When the severity of infection was adjusted at a suitable level by dilution of the inoculum, significant degrees of tolerance to early blight were found in selections of the currant tomato (*Lycopersicon pimpinellifolium*) and in *L. peruvianum*, and to a lesser extent in certain commercial varieties of *L. esculentum*.

Outstanding resistance to gray leaf spot was found in selections of *Lycopersicon pimpinellifolium* and in hybrids of *L. pimpinellifolium* × *L. esculentum*. Many selections resistant to gray leaf spot are also resistant to fusarium wilt, and some of them show a significant degree of tolerance to early blight.

No large-fruited resistant segregates were obtained from the crosses of *Lycopersicon pimpinellifolium* × large-fruited *L. esculentum*, but many selections were intermediate in size and are a definite advance toward commercial types.

In the hybrid progenies examined there were no significant correlations between resistance to *Stemphylium* and resistance to *Alternaria* as indicated by inoculations. In the trials with varieties and P. I. accessions, significant correlations were usually found.

LITERATURE CITED

(1) Andrus, C. F.
1941. PREPARATION OF INOCULUM WITH A MECHANICAL LIQUEFIER. (Phytopath. Note) Phytopathology 31: 566–567.

(2) Bohn, G. W., and Tucker, C. M.
1940. STUDIES ON FUSARIUM WILT OF THE TOMATO. I. IMMUNITY IN LYCOPERSICON PIMPINELLIFOLIUM MILL. AND ITS INHERITANCE IN HYBRIDS. Mo. Agr. Expt. Sta. Res. Bul. 311, 82 pp., illus.

(3) Kunkel, L. O.
1918. A METHOD OF OBTAINING ABUNDANT SPORULATION IN CULTURES OF MACROSPORIUM SOLANI E. & M. Brooklyn Inst. Arts and Sci., Bot. Gard. Mem. 1: 306–312, illus.

(4) Porte, William S., and Walker, H. B.
1941. THE PAN AMERICA TOMATO, A NEW RED VARIETY HIGHLY RESISTANT TO FUSARIUM WILT. U. S. Dept. Agr. Cir. 611, 6 pp., illus.

(5) ——— and Wellman, Frederick L.
1941. DEVELOPMENT OF INTERSPECIFIC TOMATO HYBRIDS OF HORTICULTURAL VALUE AND HIGHLY RESISTANT TO FUSARIUM WILT. U. S. Dept. Agr. Cir. 584, 19 pp., illus.

(6) Rands, R. D.
1917. THE PRODUCTION OF SPORES BY ALTERNARIA SOLANI IN PURE CULTURE. (Phytopath. Note) Phytopathology 7: 316–317, illus.

(7) Weber, George F.
1929. A STEMPHYLIUM LEAF SPOT OF TOMATOES. (Abstract) Phytopathology 19: 92.

(8) ———
1930. GRAY LEAF SPOT OF TOMATO CAUSED BY STEMPHYLIUM SOLANI, SP. NOV. Phytopathology 20: 513–518.

(9) ——— Hawkins, Stacy, and Kelbert, David, G. A.
1932. GRAY LEAFSPOT, A NEW DISEASE OF TOMATOES. Fla. Agr. Expt. Sta. Bul. 249, 35 pp., illus.

(10) Wiltshire, S. P.
1933. THE FOUNDATION SPECIES OF ALTERNARIA AND MACROSPORIUM. Brit. Mycol. Soc. Trans. 18: 135–160, illus.

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